

# How Complementary are SRTM X- and C-band data?

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**Jörn Hoffmann, Diana Walter**

**German Aerospace Center (DLR)  
German Remote Sensing Data Center (DFD)**

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- Comparing the two SRTM DEMs
  - Completeness
  - Differences
  - Accuracy
- Merging C- and X-band data
- Analyzing the improvements



# SRTM – Elevation Models

SRTM C-

Parameter	Band	SRTM X-Band
wavelength	5.6 cm	3.1 cm
carrier frequency	5.3 GHz	9.6 GHz
polarization	Dual	VV
incidence angle (center)	45°	55°
swath width	225 km	50 km
relative vertical accuracy <sup>1</sup>	10 m	6 m
absolute vertical accuracy <sup>1</sup>	16 m	16 m
relative horizontal accuracy <sup>2</sup>	15 m	15 m
accuracy <sup>2</sup>	20 m	20 m
elevation steps	1 m	1 m
grid raster size	1“ (30m)	1“
vertical datum	EGM96	WGS84 o. MSL
horizontales datum	WGS84	WGS84

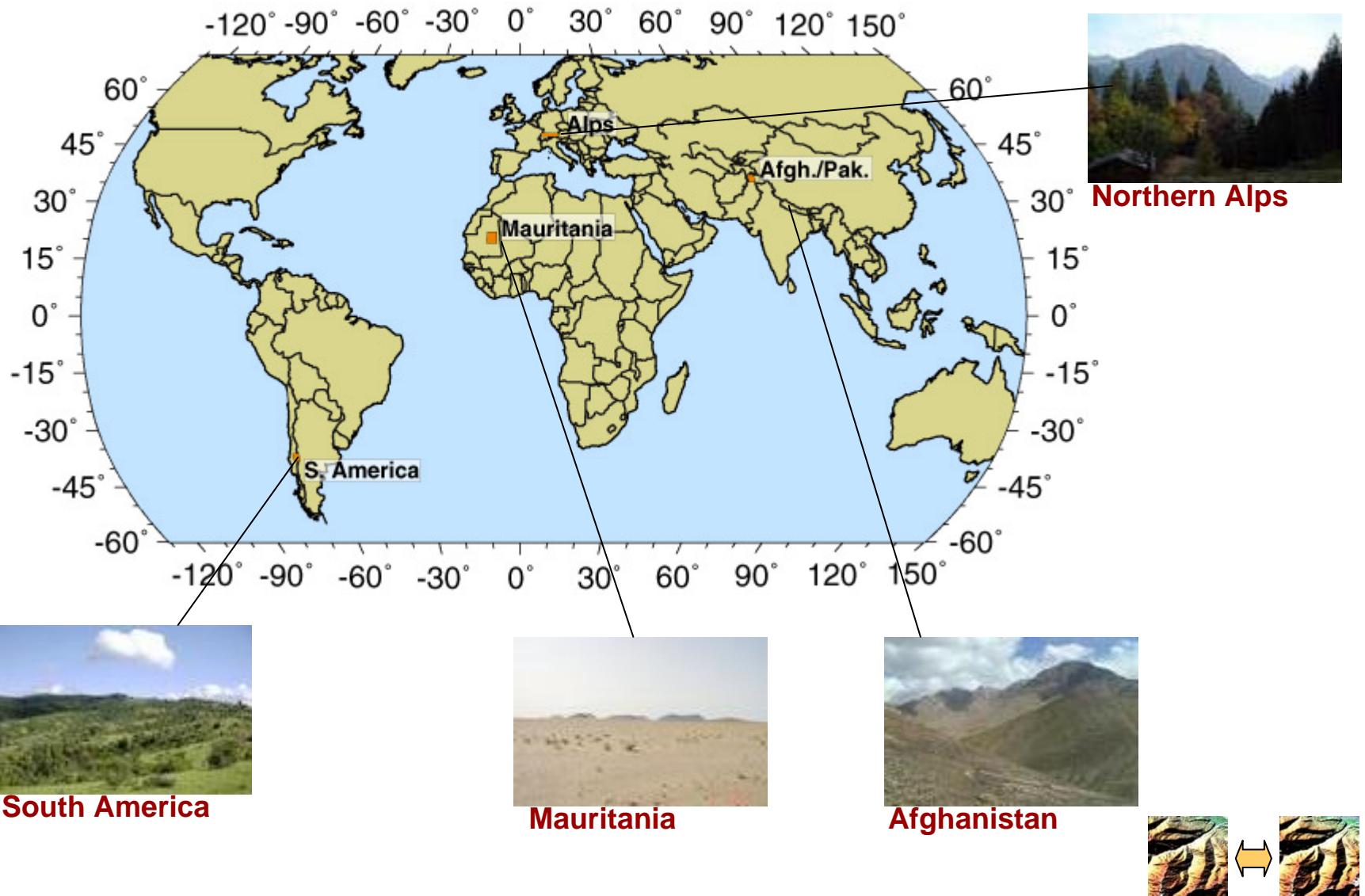
<sup>1</sup> 90% vertical error

<sup>2</sup> 90% circular error

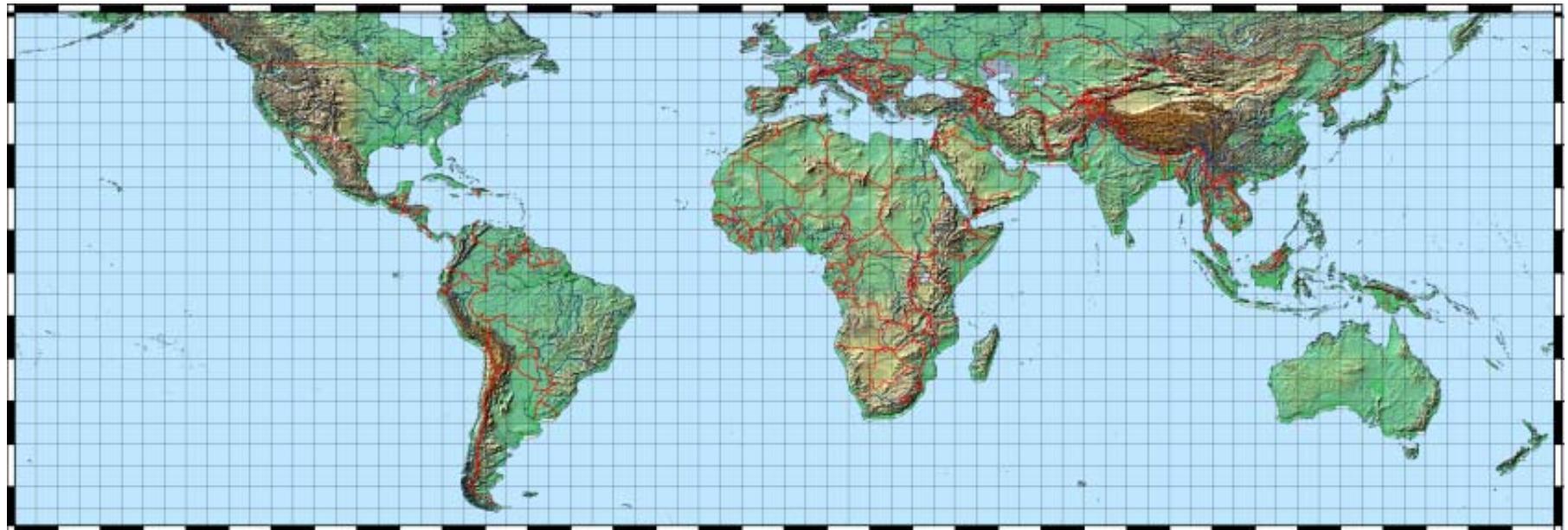
What can be gained by combining both DEMs?



# Test areas



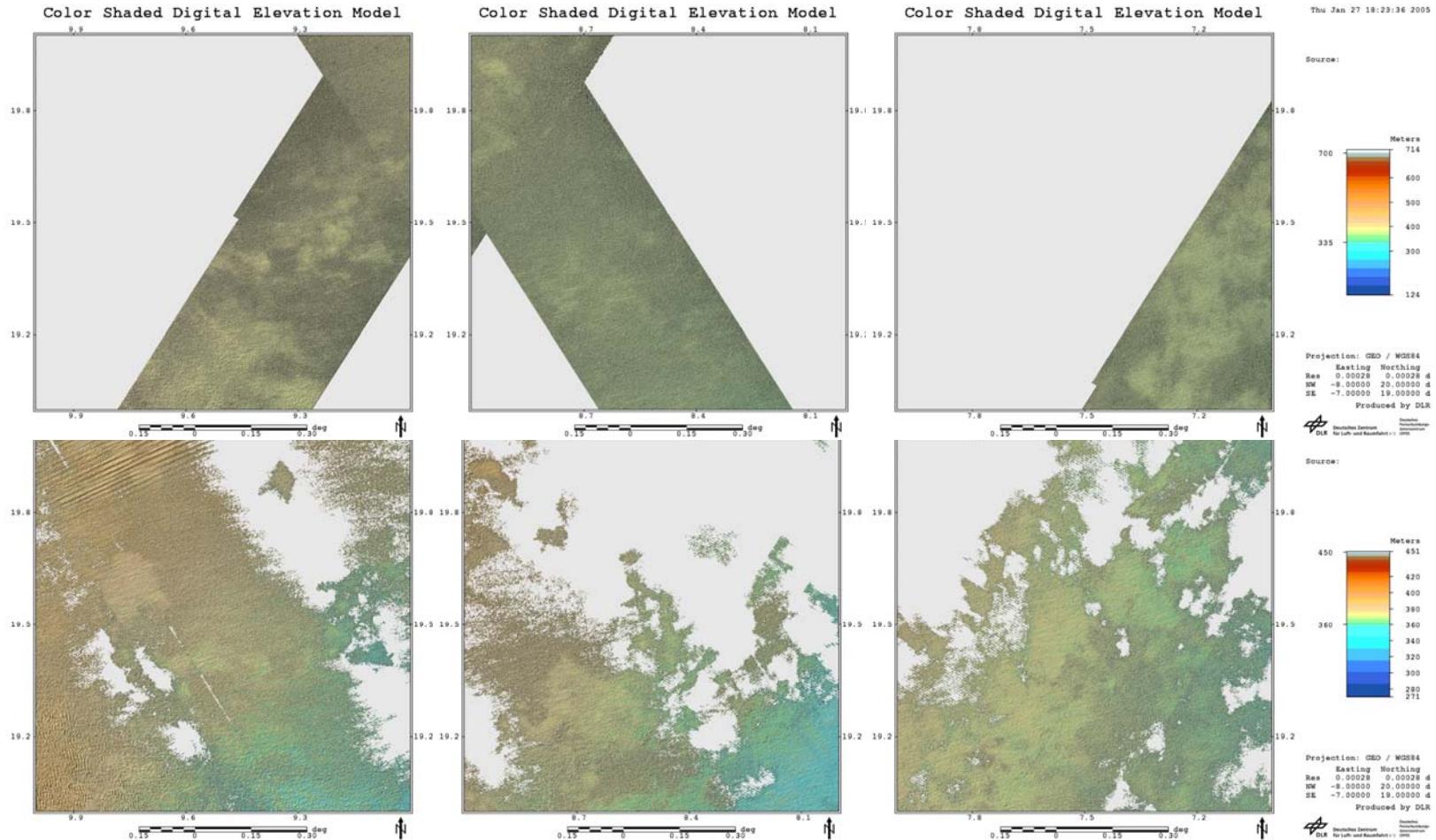
# Relative comparison of X- and C-band DEMs



- **C-band is more complete than X-band:**
  - **X-band: 40%**
  - **C-band: 80%**



# Relative comparison of X- and C-band DEMs



- Void regions are distributed differently in the two DEMs

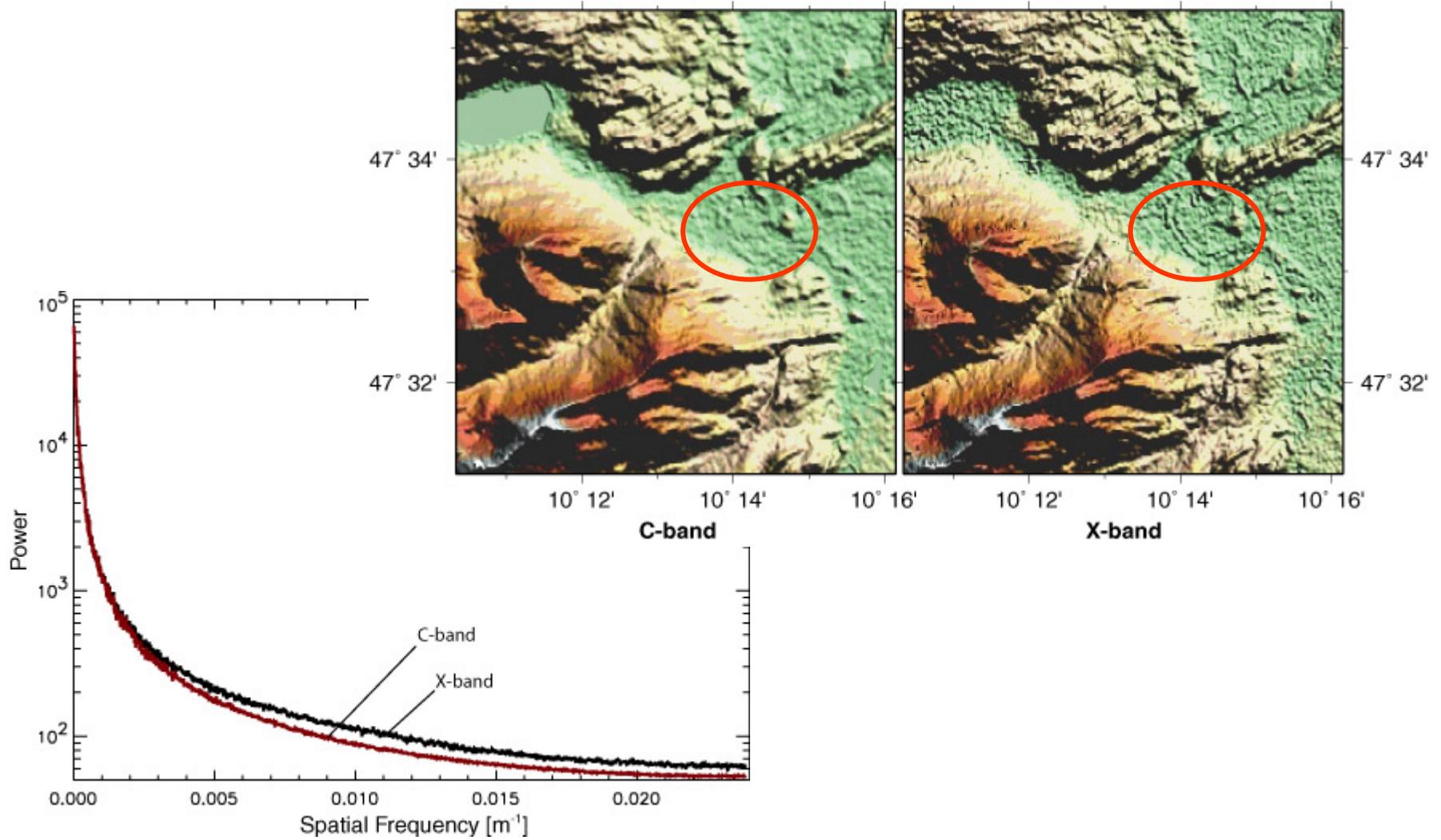


# Completeness can be improved significantly

Test area	Invalids C-band	Invalids X-band	No acquisition in X-band	Holes fillable in C-band	Invalid in C- and X-band
Northern Alps	2.3%	0.0%	34.3%	52.7%	1.1%
Afghanistan	20.4%	6.0%	59.4%	22.2%	16%
Mauritania	40.1%	0.0%	66.8%	29.3%	29.8%
South America	0.3%	0.0%	44.4%	36.7%	0.1%

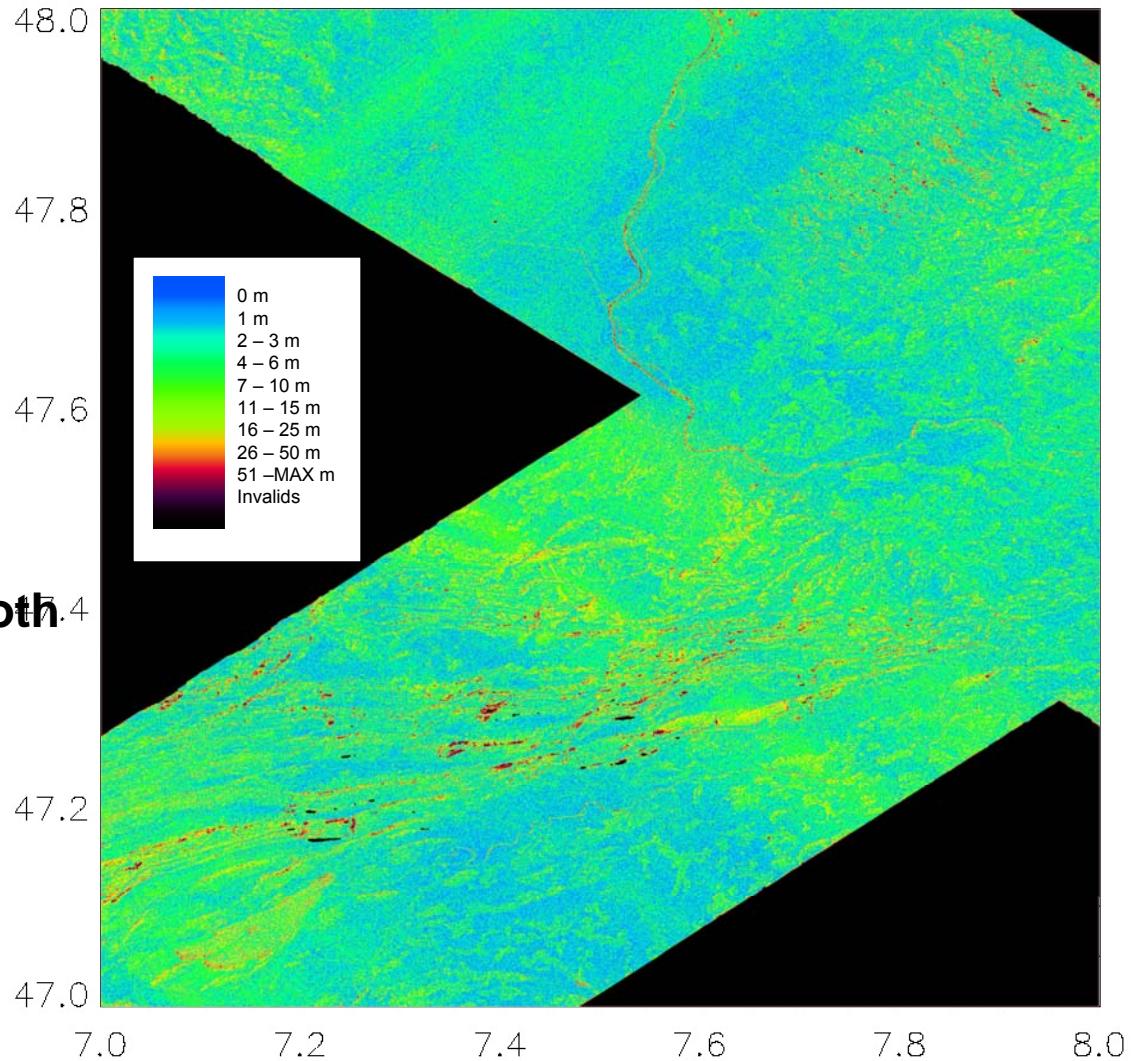


# C-band DEM is smoother than X-band DEM

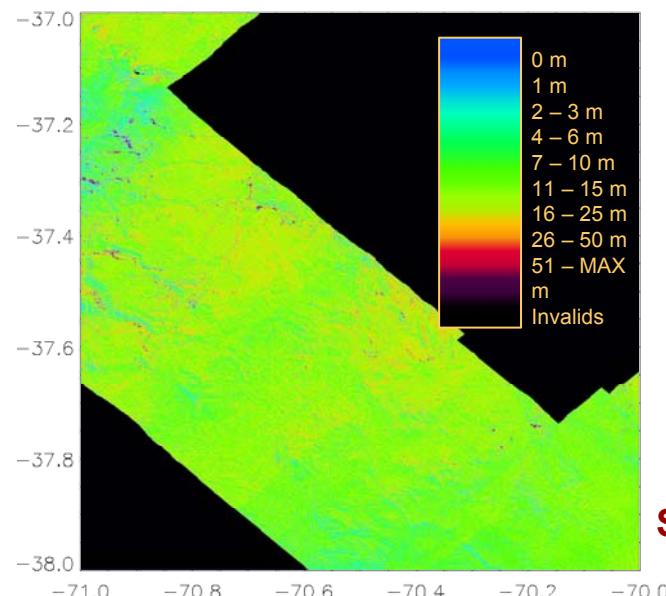
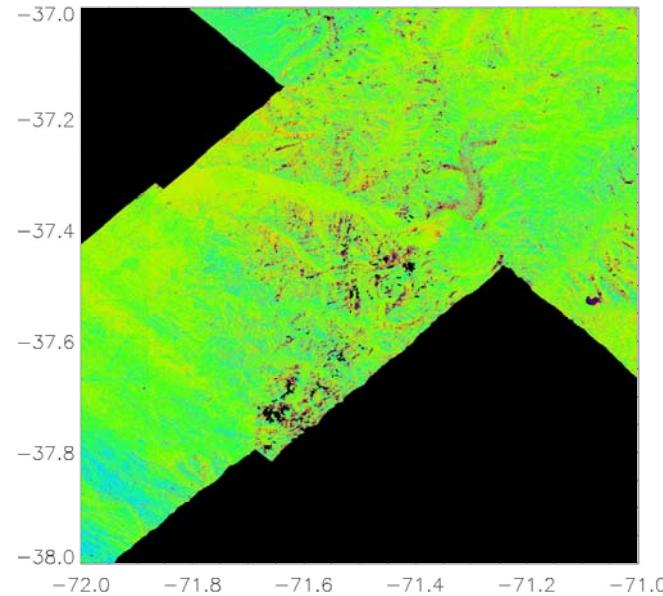


## Differences between C- and X-band are small

- Slight differences occur both at large and small scales
- Problems particularly on:
  - steep slopes
  - water bodies



# Large-scale offsets can be many meters



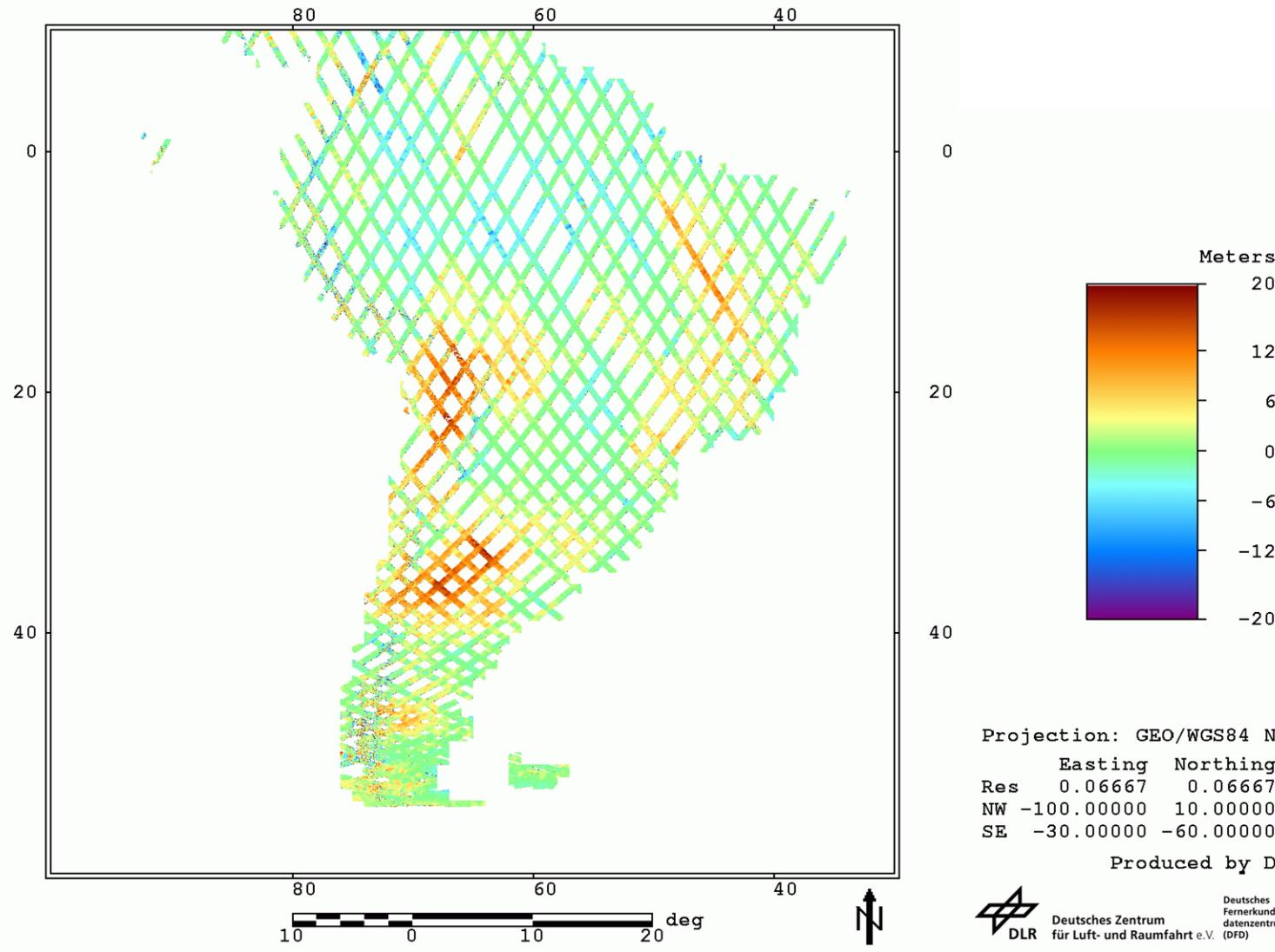
South America

- In some regions, low-frequency offsets occur



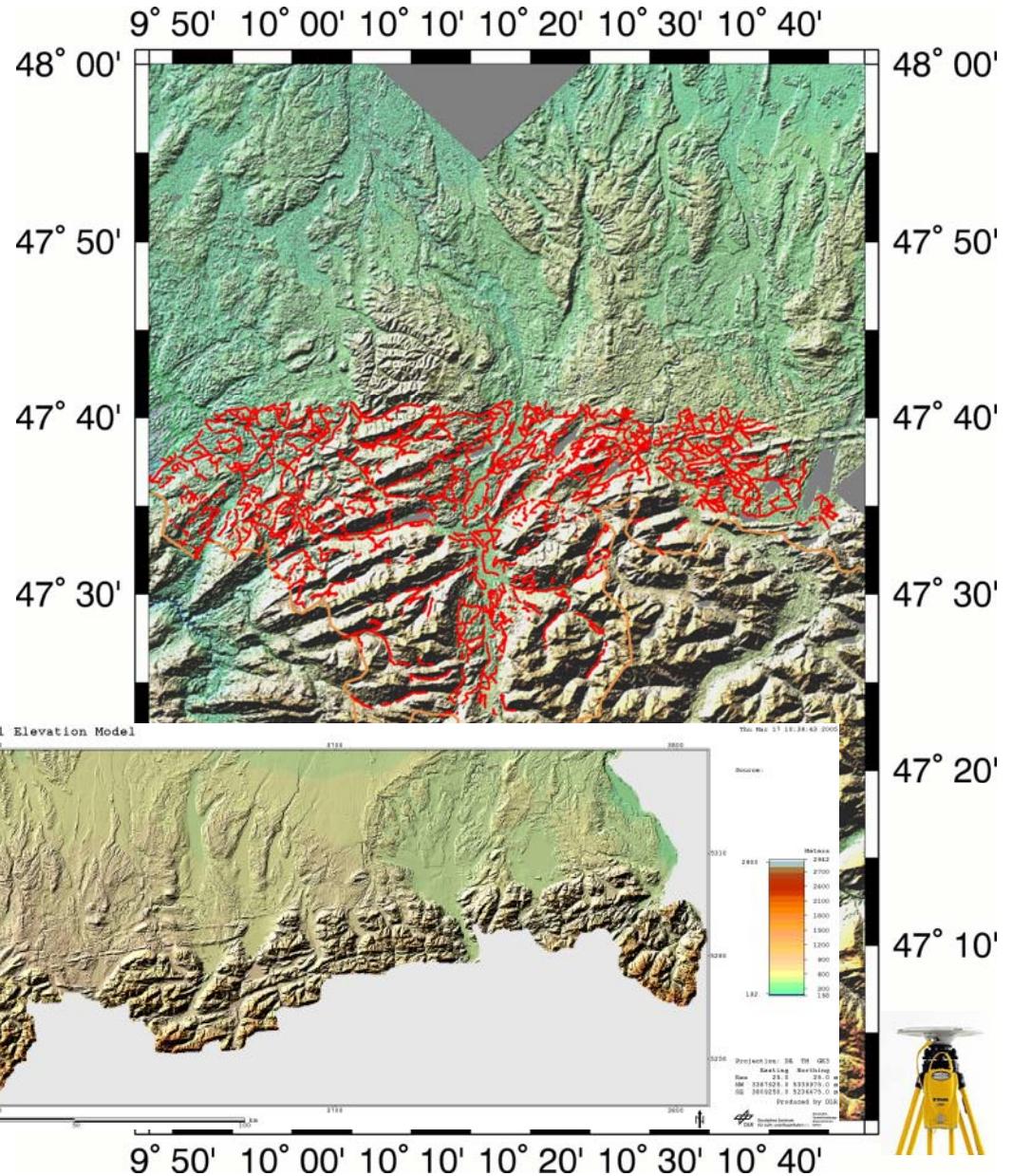
# Large-scale offsets can be many meters

Colored Digital Elevation Model

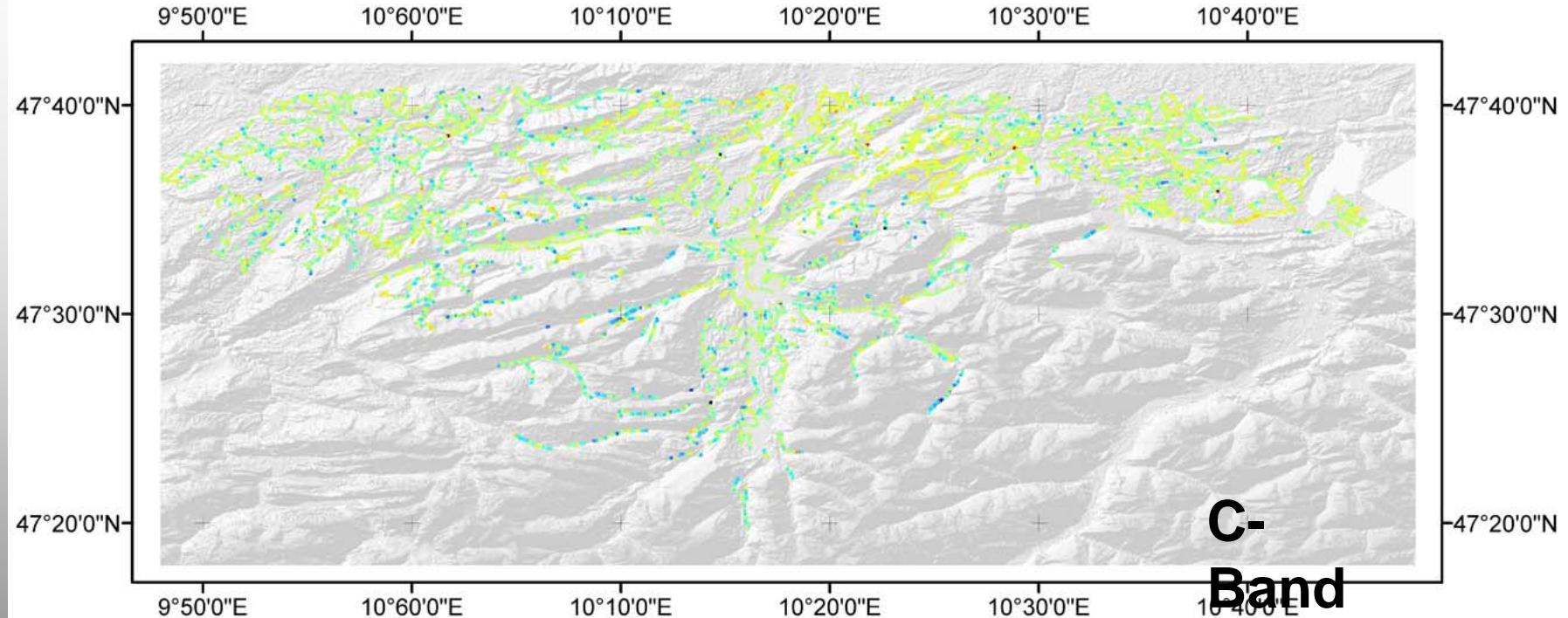


# Accuracies in the test area Northern Alps

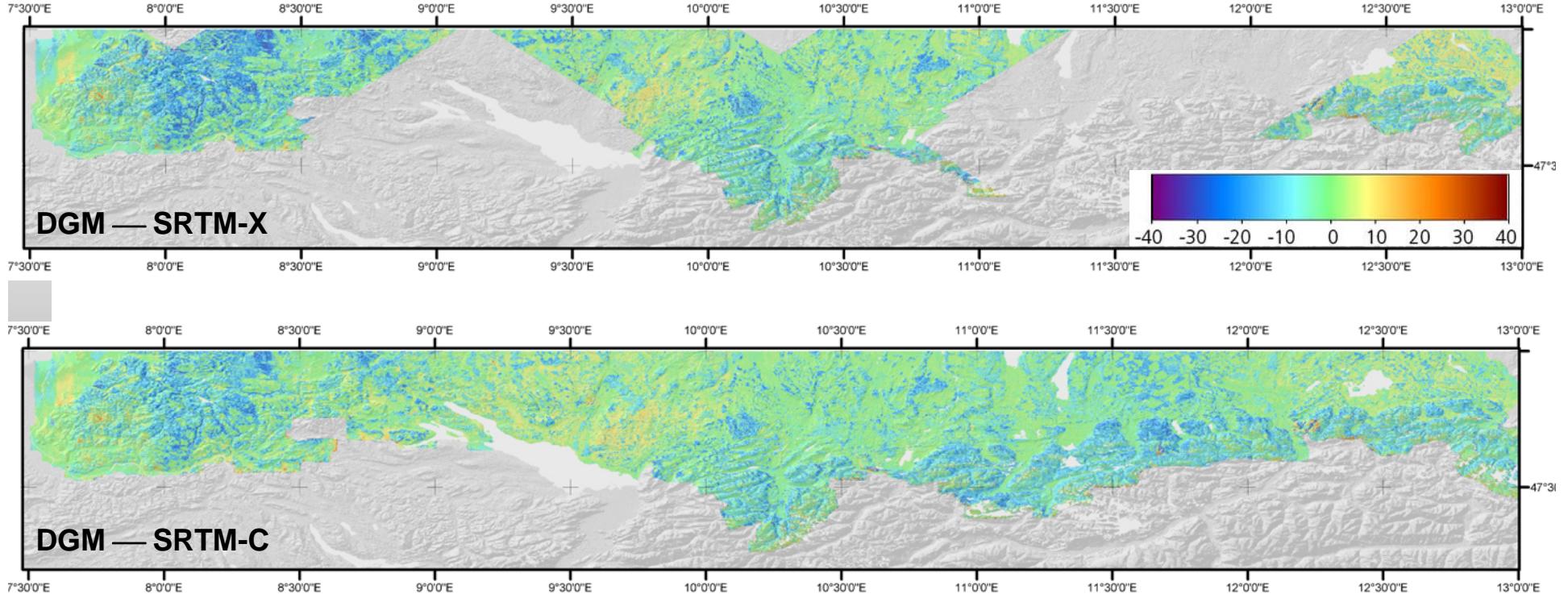
- Two types of reference information:
  - GPS-Tracks
    - $\sigma \sim m$
    - Profile information
    - WGS 84
  - DGM-D 25
    - $\sigma \sim 10m$
    - Area information
    - Gauss-Krüger



# Absolute accuracies of C-/X-band are comparable



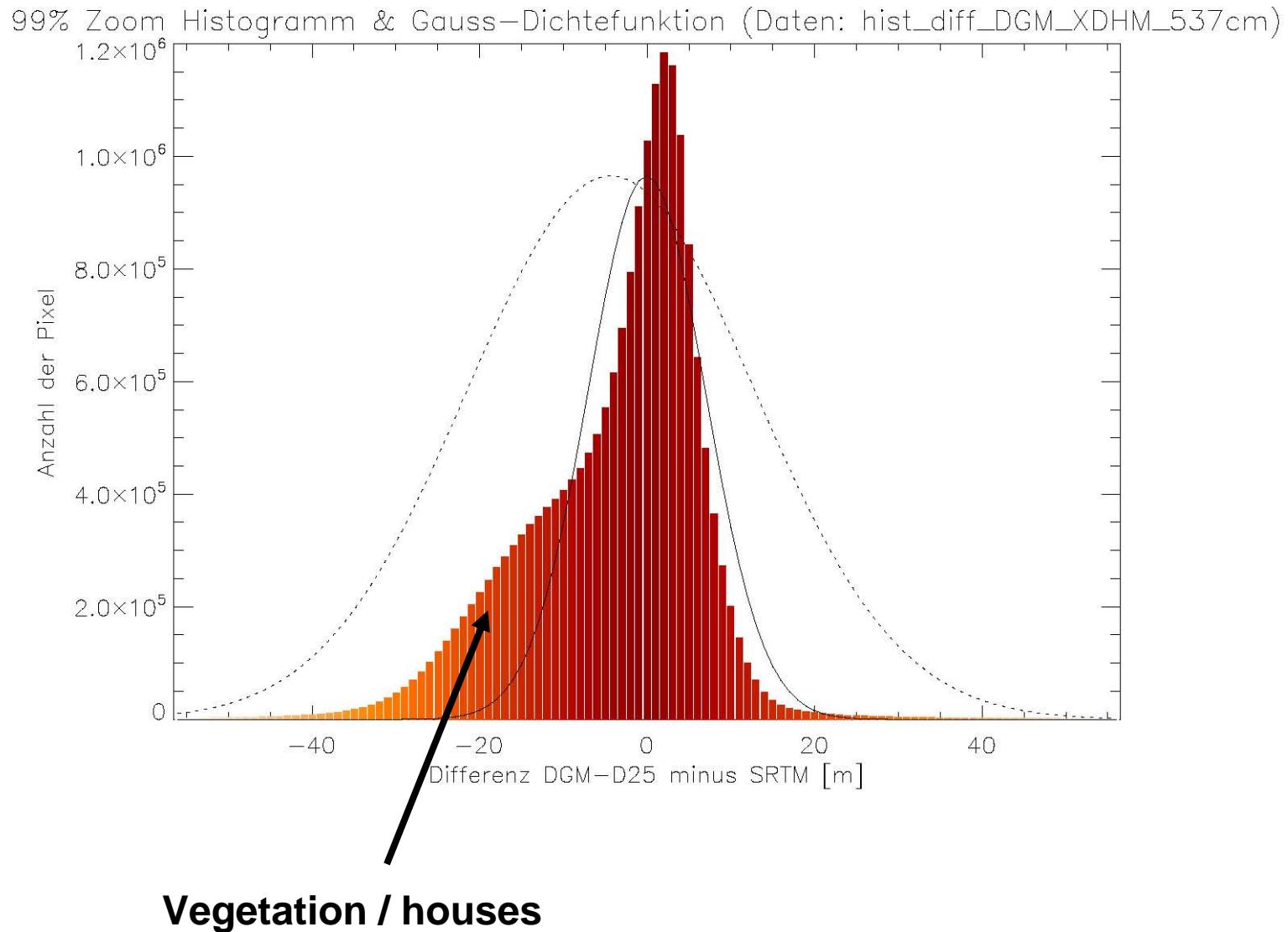
# Comparison between reference model and SRTM



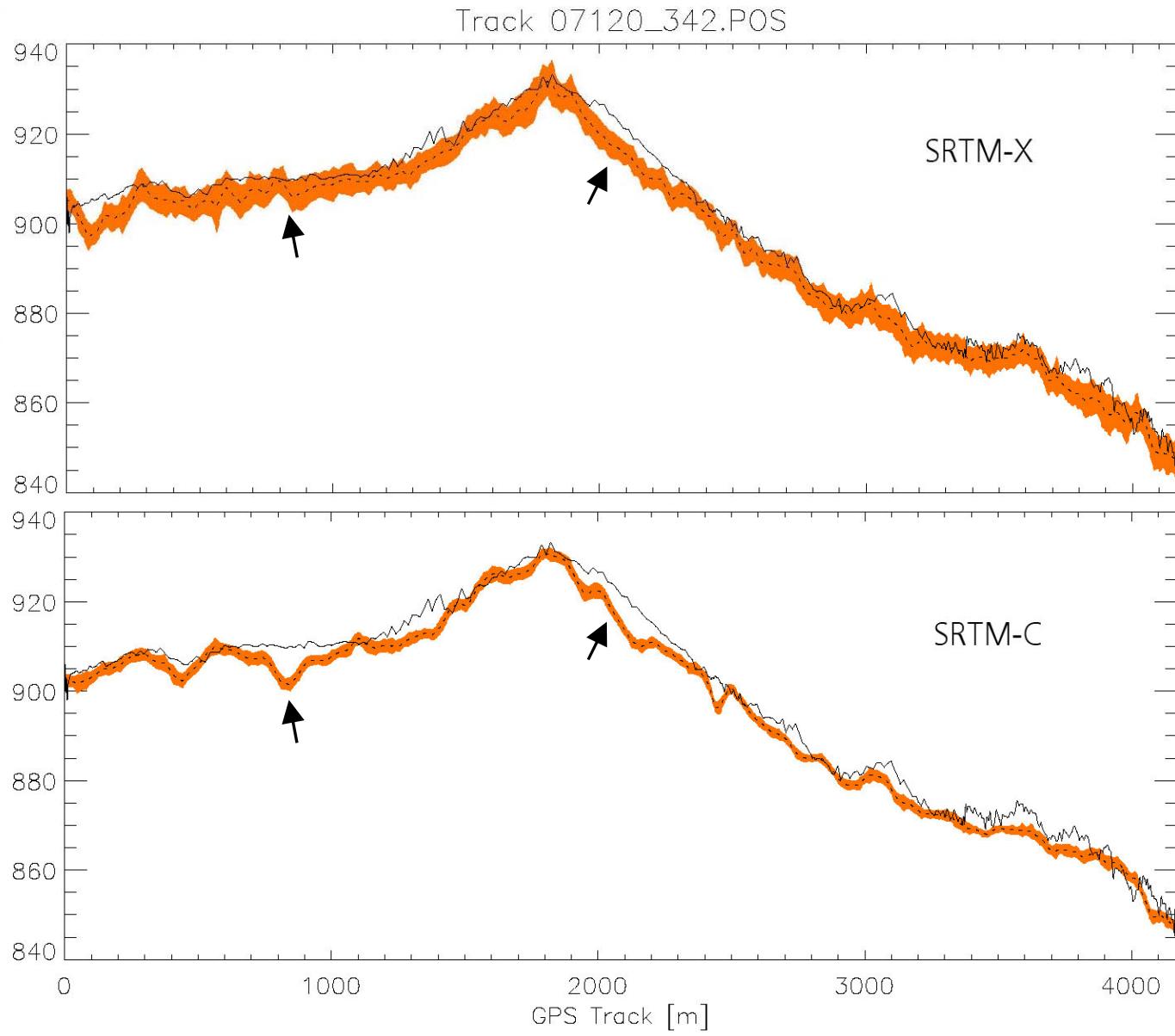
- SRTM-DEM<sup>s</sup> more similar to each other than to reference
- On average, SRTM-DEM<sup>s</sup> slightly too high



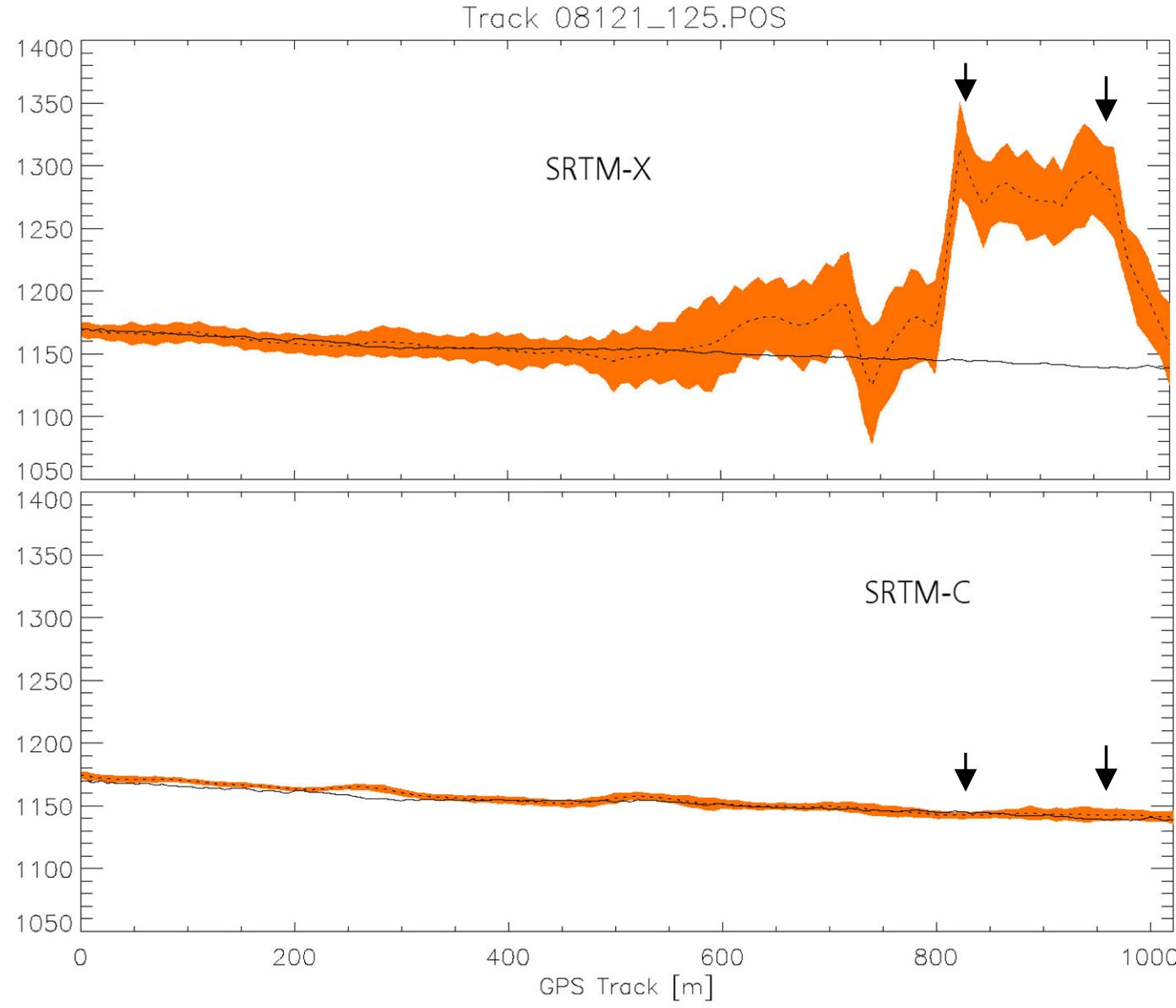
## Statistics reveals difference between DSM and DEM



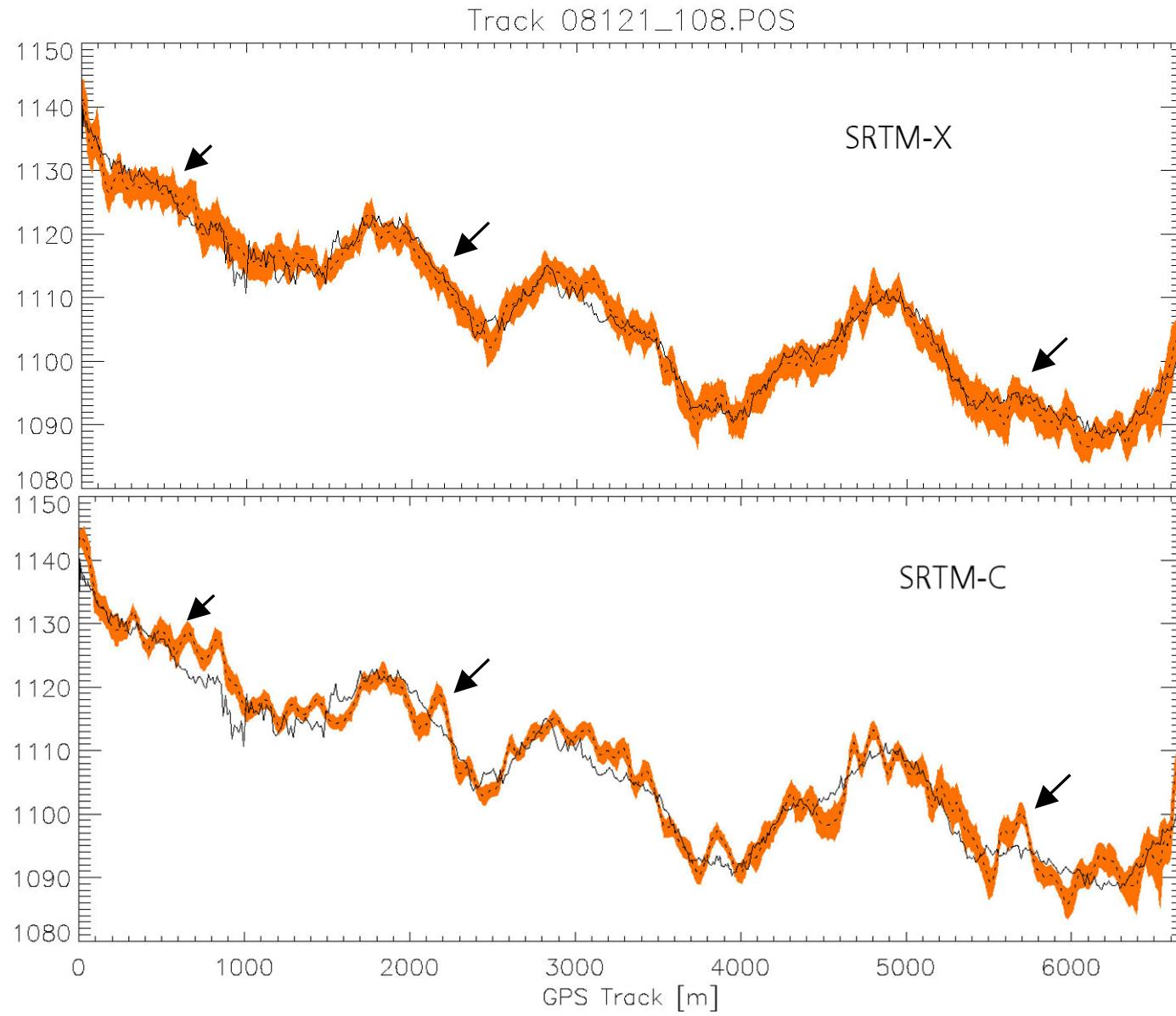
## C-band DEM is smoother



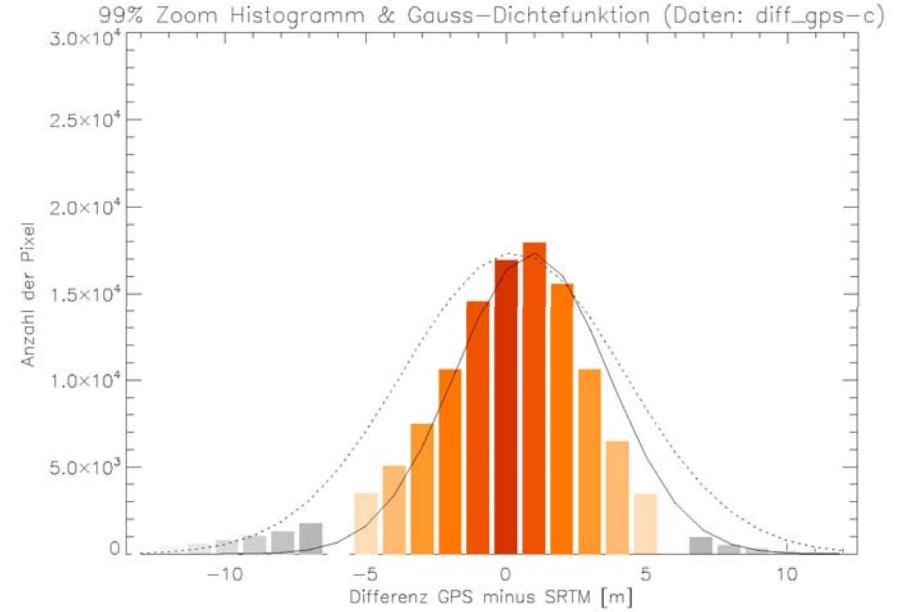
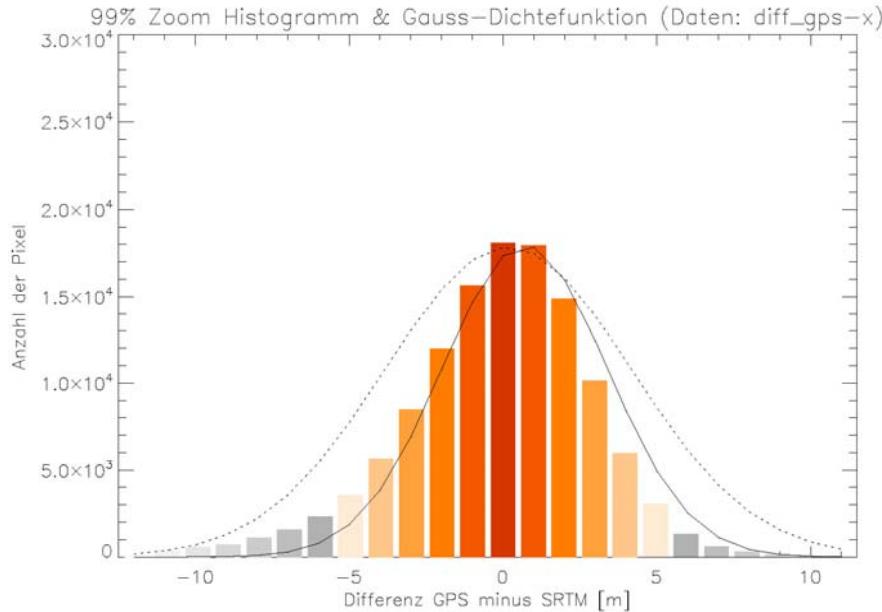
# X-band DEM contains more unwrapping errors



## Quality of C- and X-band are similar



# Quality of C- and X-band are similar



- Only minimal statistical differences of absolute accuracies in test areas

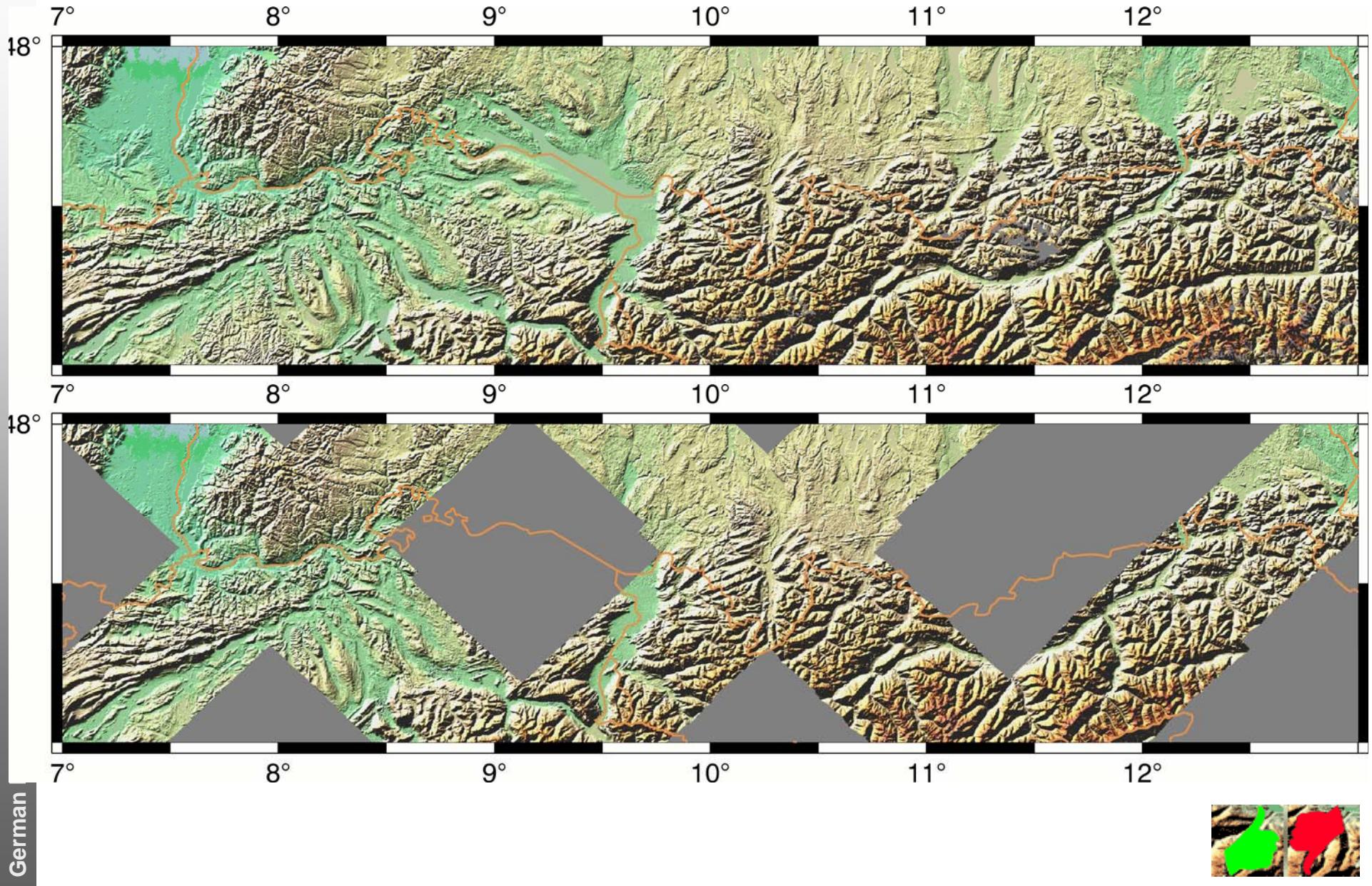
	X-Band DHM	C-Band DHM
Minimum [m]	-167,82	-45,39
Maximum [m]	53,52	52,04
Mean [m]	0,17	0,26
Standard deviation [m]	3,99	3,90
Median [m]	0,55	0,73
99,9% of differences [m]	$\pm 24$	$\pm 21$
99,0% of differences [m]	$\pm 12$	$\pm 13$
90% of differences [m]	$\pm 5$	$\pm 5$
68% of differences [m]	$\pm 2$	$\pm 3$
50% of differences [m]	$\pm 1$	$\pm 2$



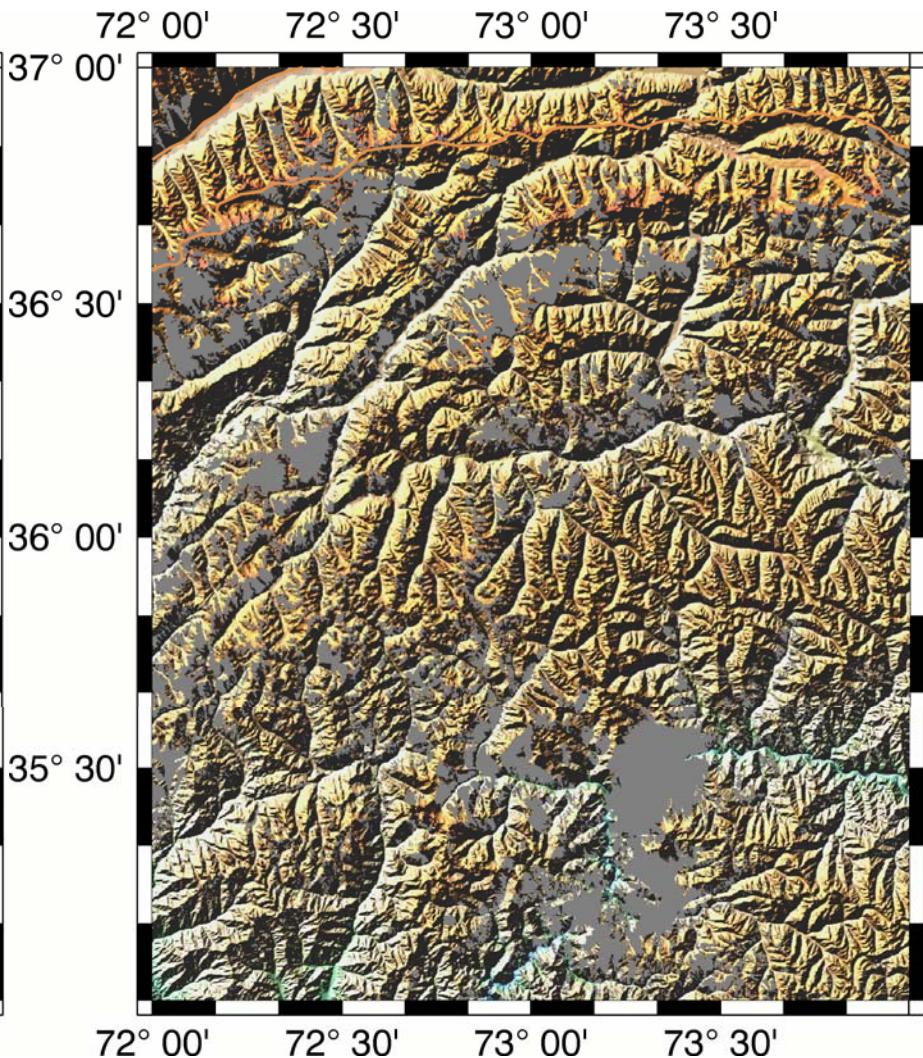
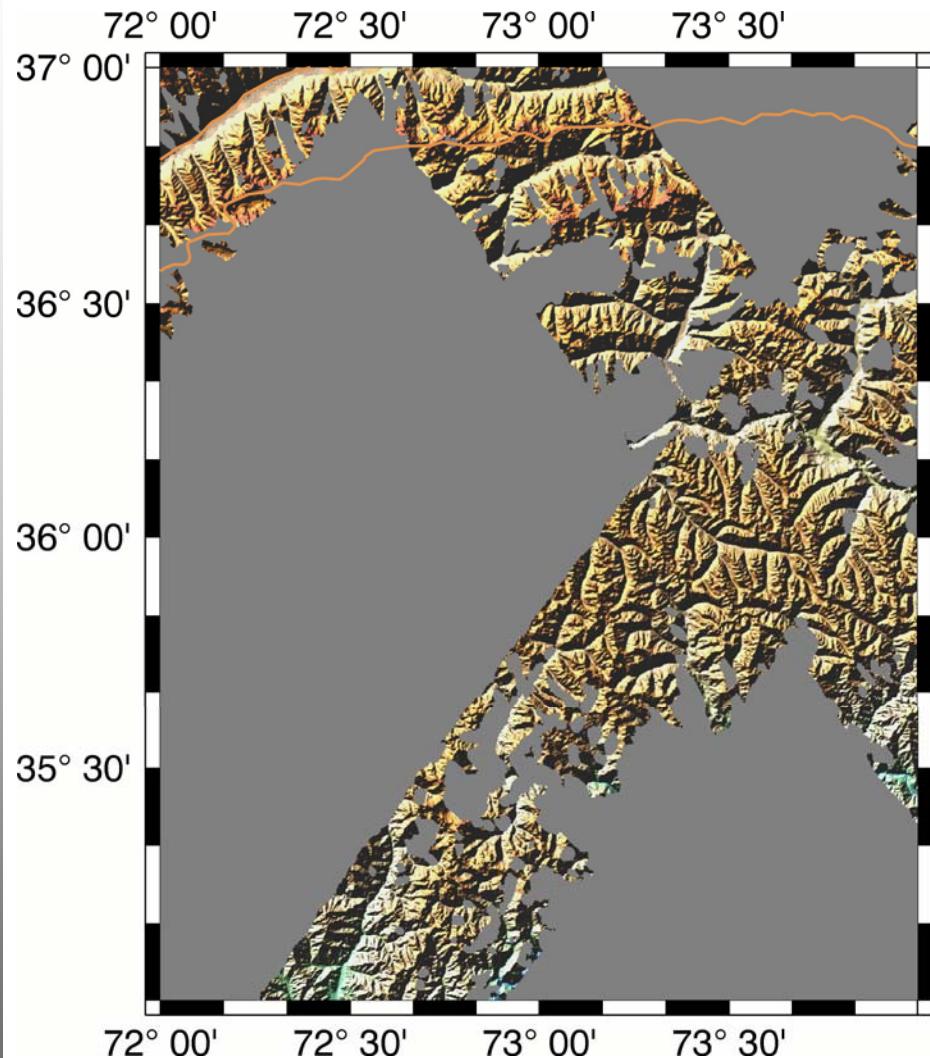
- **Masking water bodies in X-band DEM**
- **Detecting and masking outliers in X-band DEM**
- **Removal of constant offset**
- **Weighted average using error information**
- **Error propagation**



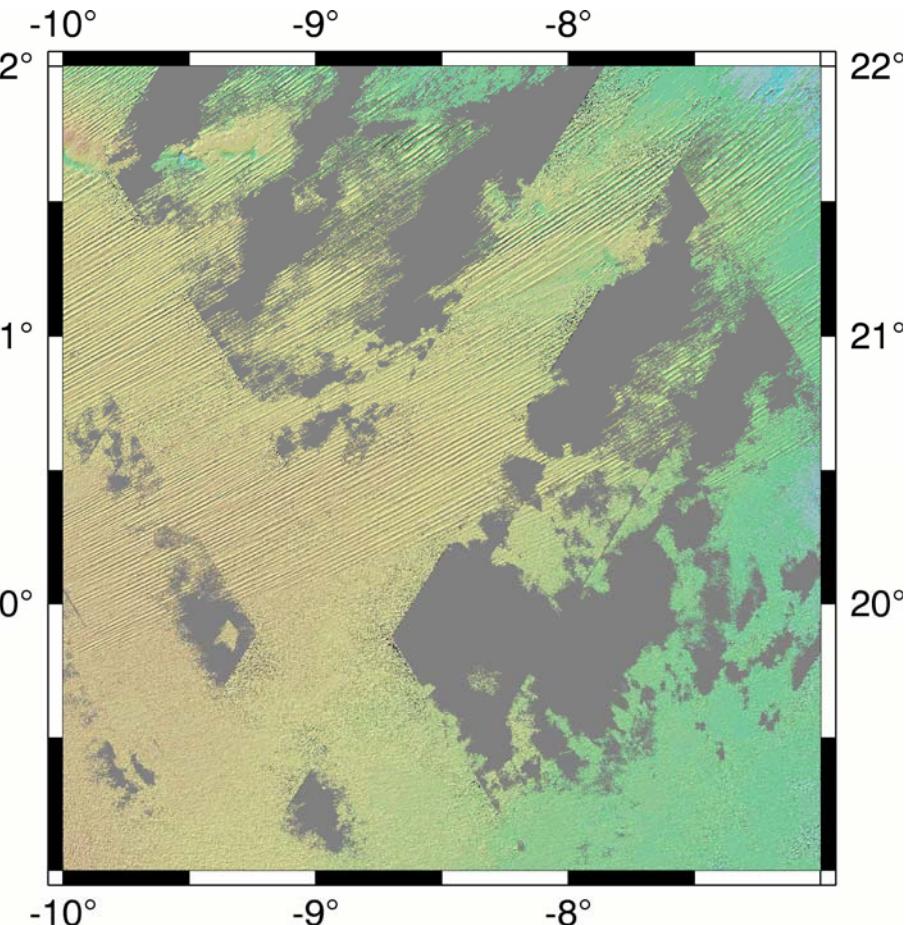
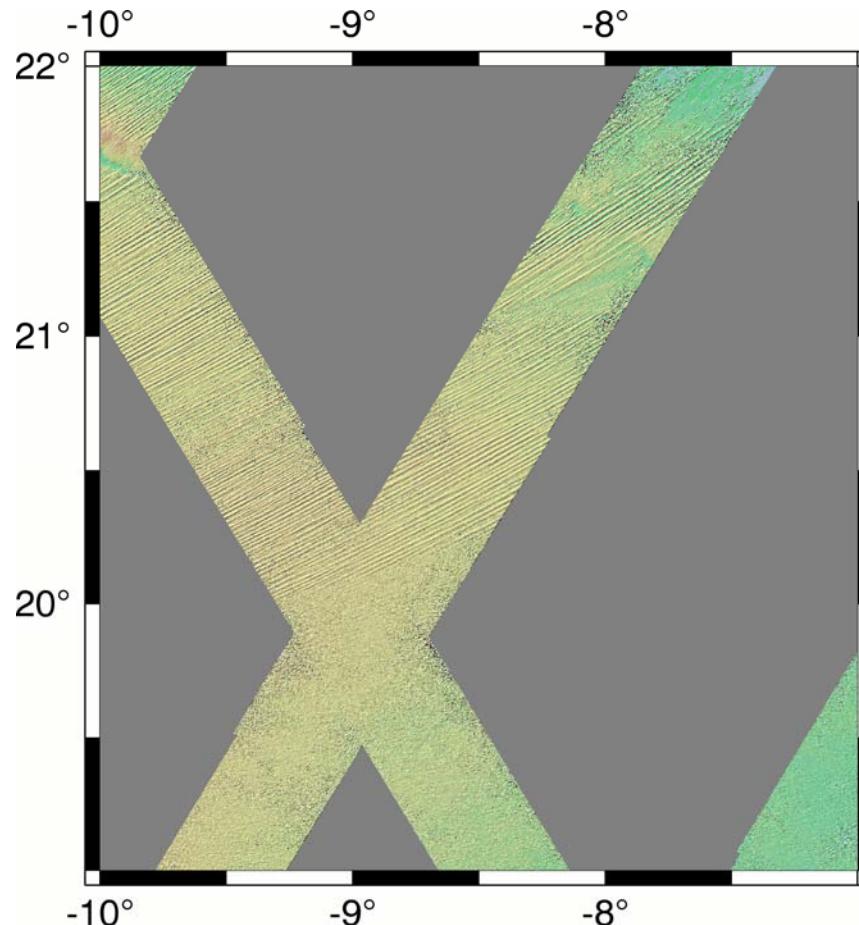
# Result: Northern Alps



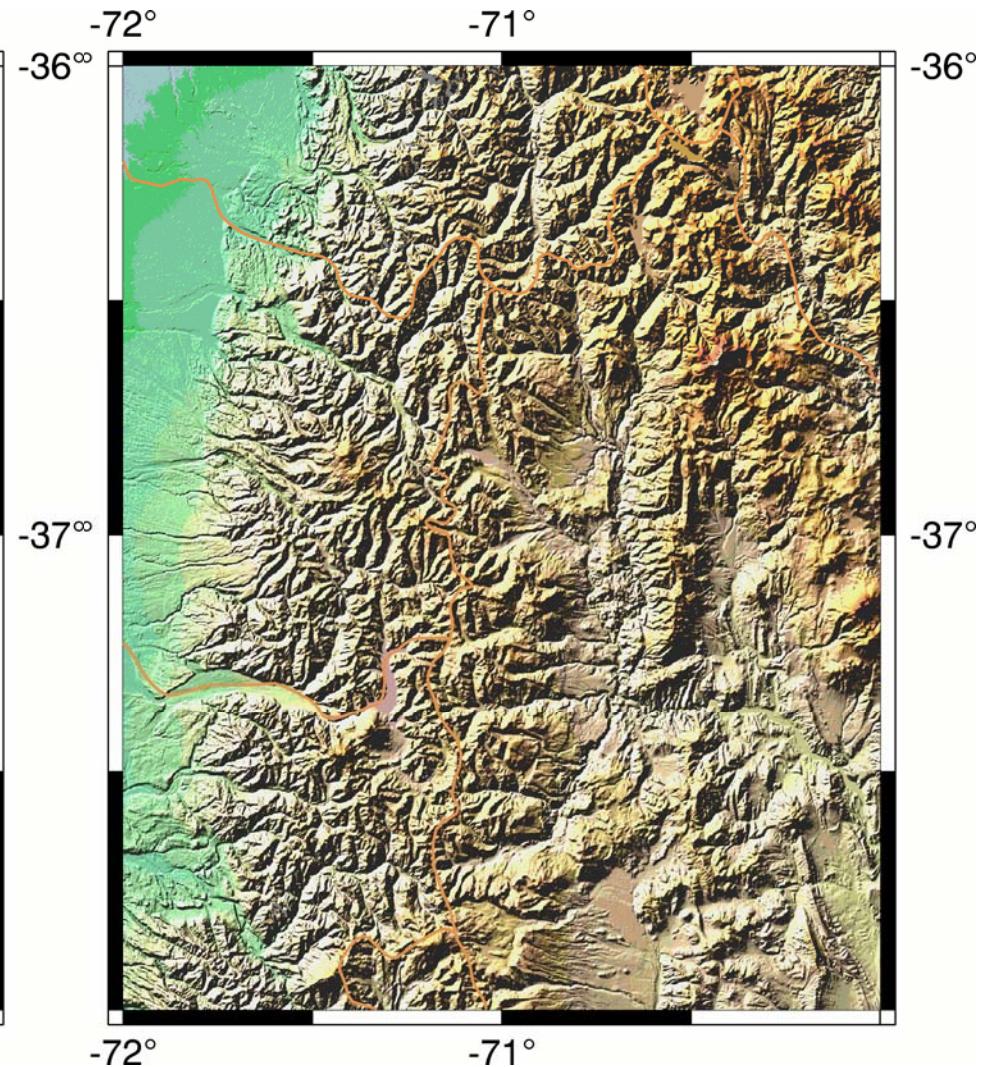
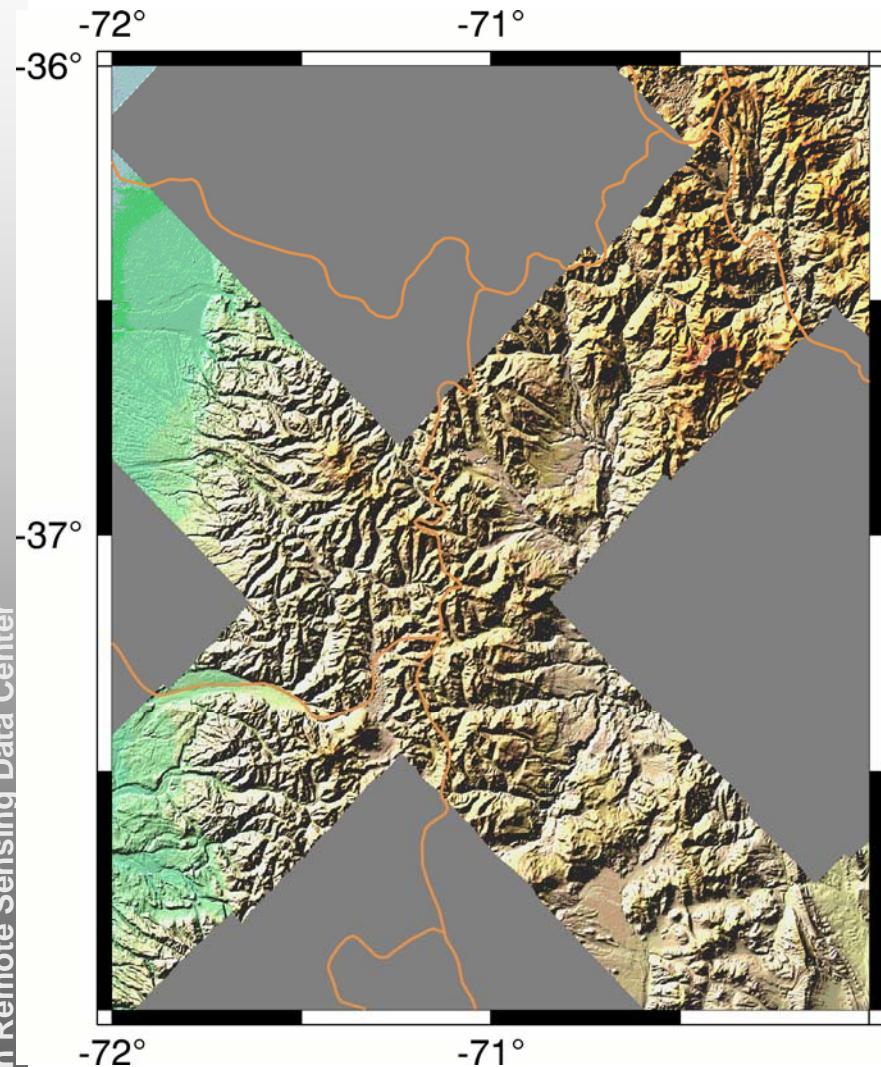
# Result: Afghanistan



# Result: Mauritania



# Result: South America

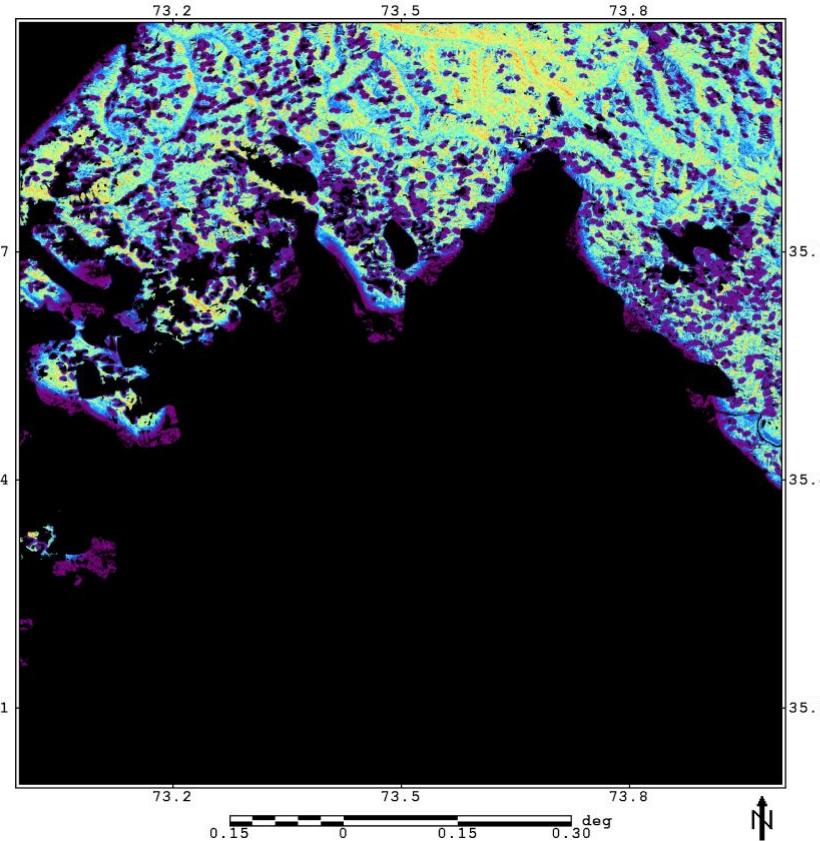


# Statistical Errors decrease

Color Shaded Digital Elevation Model

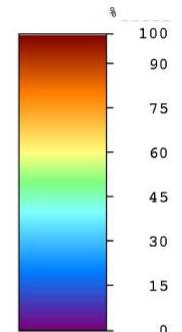


Percent Improvement over C-Band



Tue Apr 19 14:56:32 200

Source:



Projection:  
 Res 0.00028 0.00028  
 NW 73.00000 36.00000  
 SE 74.00000 35.00000

Produced by DLR

 Deutsches Zentrum für Luft- und Raumfahrt e.V.



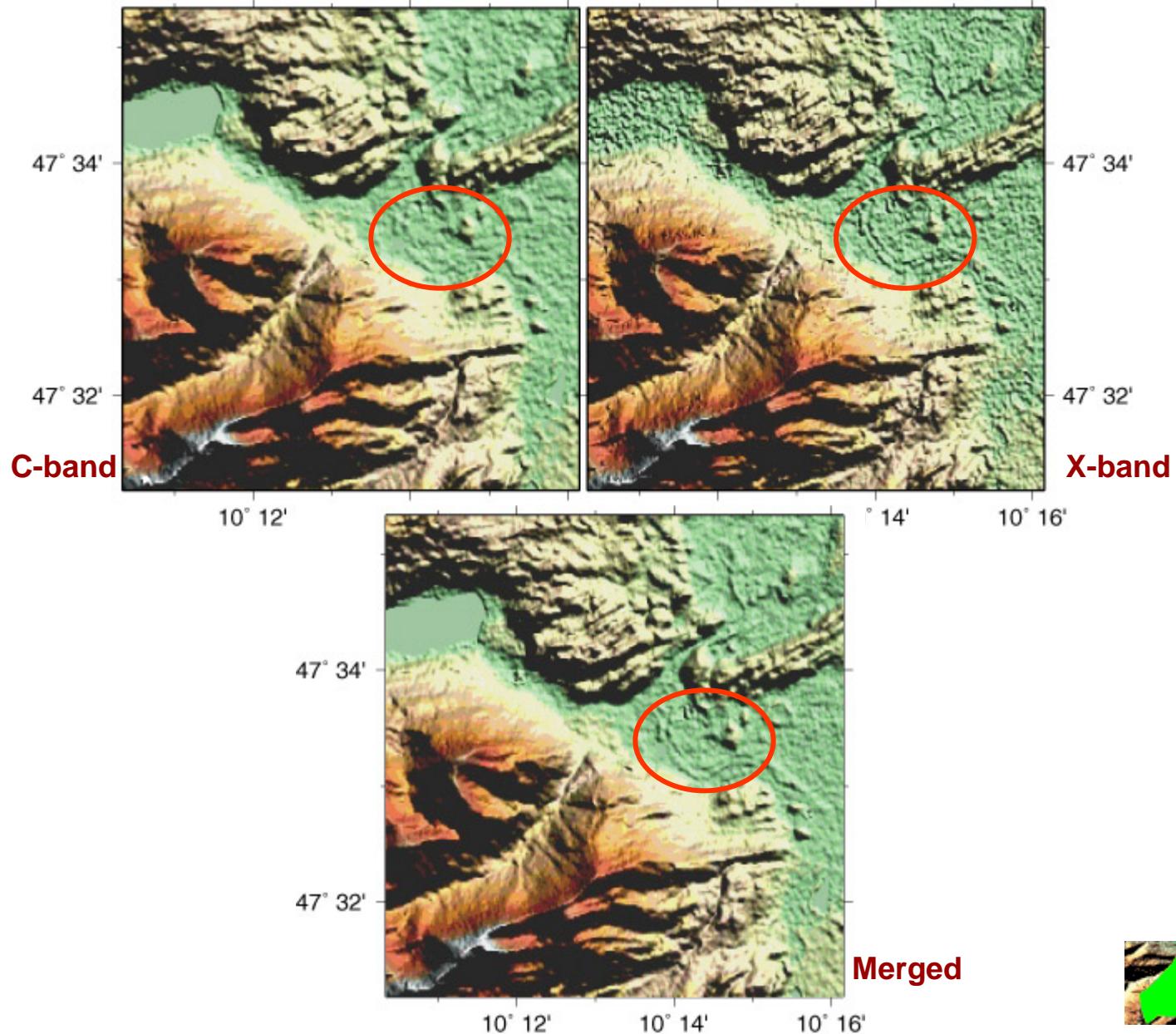
# Absolute accuracy improves

	X-band DEM	C-band DEM	CX DEM
Minimum [m]	-167,82	-45,39	<b>-45,67</b>
Maximum [m]	53,52	52,04	52,04
Mean [m]	0,17	0,26	-0,32
Standard deviation [m]	3,99	3,90	<b>3,39</b>
Median [m]	0,55	0,73	<b>0,10</b>
99,9% of differences [m]	± 25	± 23	<b>± 21</b>
99,0% of differences [m]	± 12	± 14	<b>± 13</b>
90% of differences [m]	± 5	± 6	<b>± 5</b>
68% of differences [m]	± 3	± 3	± 3
50% of differences [m]	± 2	± 2	± 2

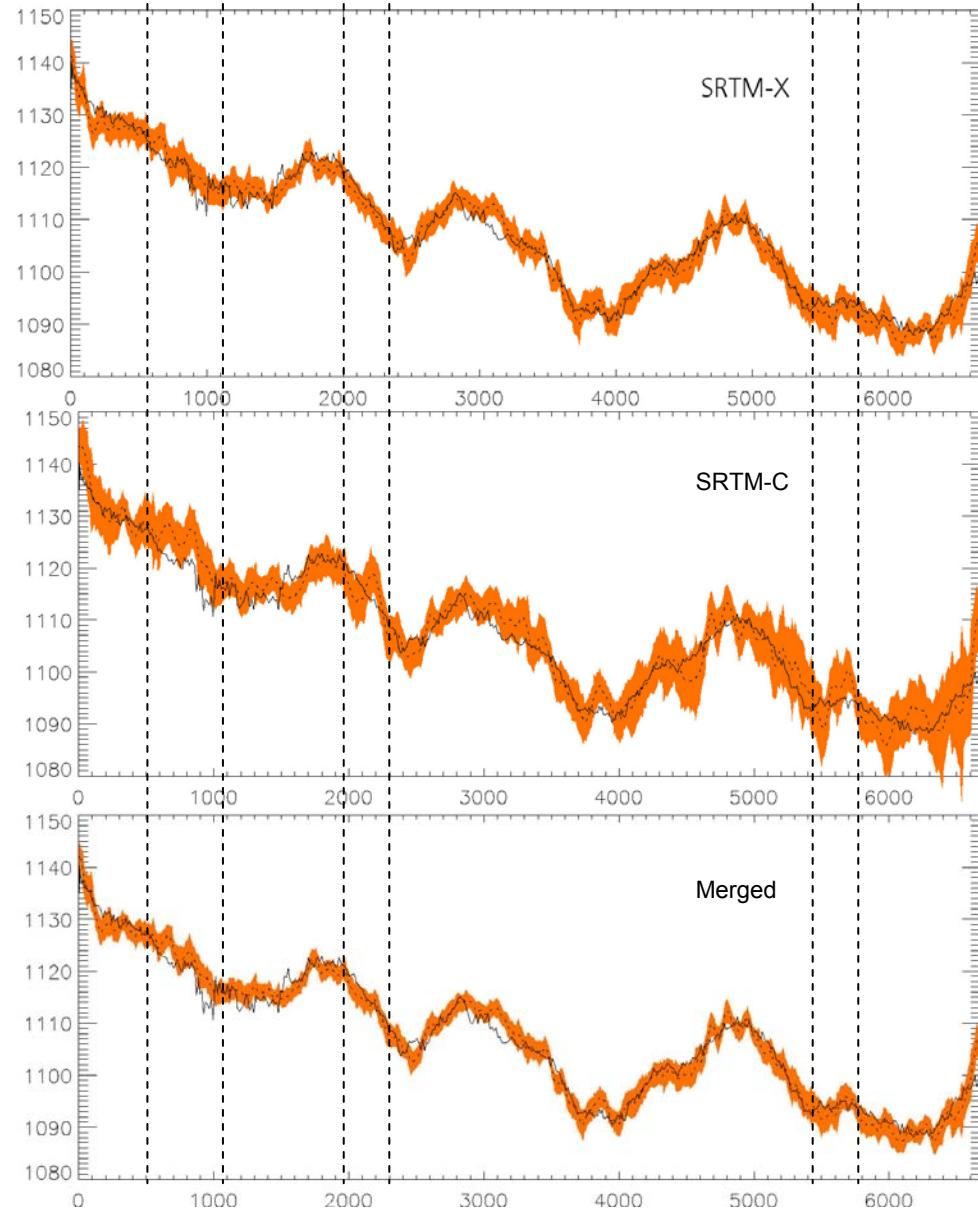
**Improvement of absolute accuracy for test area Northern Alps**



## Merging combines characteristics of both inputs



# Improvements detailed

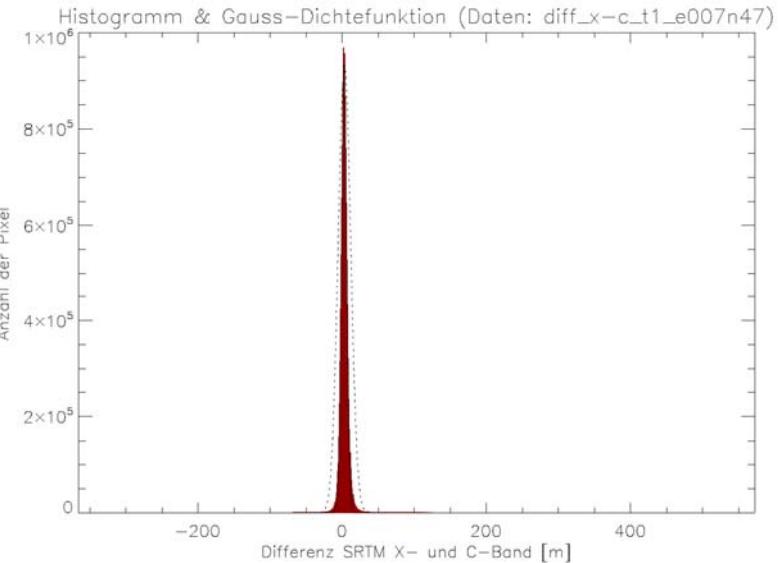
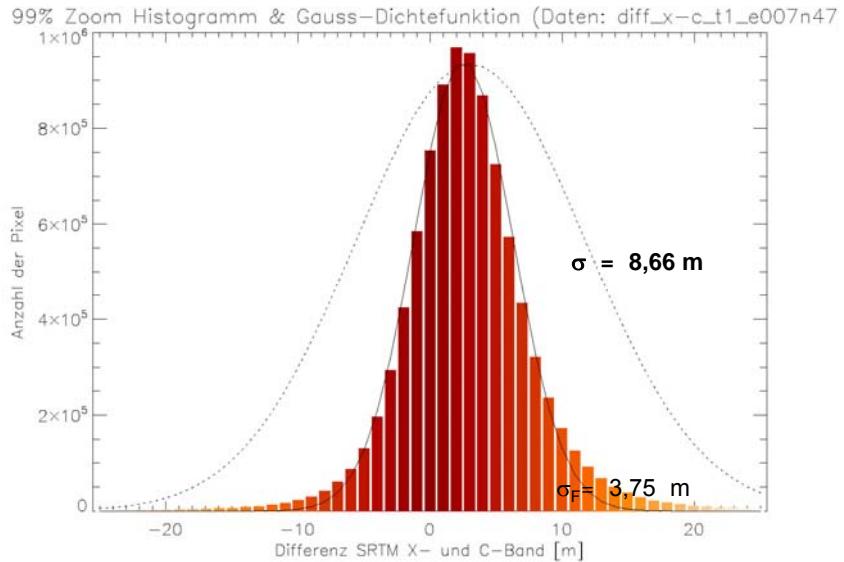


- **Improvements:**
  - Reducing deviations from reference
  - Smaller standard error

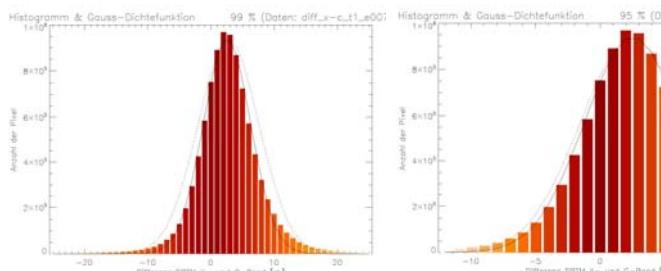


- The DEMs derived from the C- and X-band data of the SRTM mission are of similar quality and fulfill their overall product specifications
- Combining both DEMs we can gain
  - Completeness (even at C-band)
  - Smaller error bands

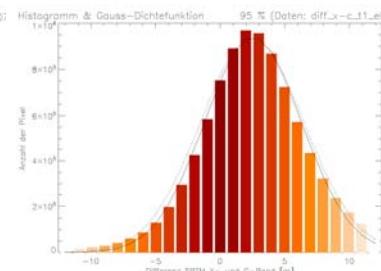
# Fehlerverteilung



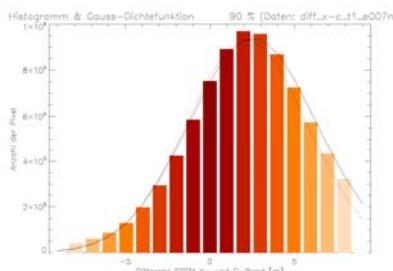
- Fehler scheinen nicht normalverteilt zu sein...



$$\mu = 2,78 \text{ m}, \sigma = 4,83 \text{ m}$$



$$\mu = 2,48 \text{ m}, \sigma = 4,01 \text{ m}$$



$$\mu = 2,18 \text{ m}, \sigma = 3,56 \text{ m}$$

... sind es aber im Wesentlichen

